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EVALUATION OF ALSYS_037
Ada COMPILER

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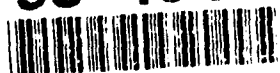
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13. ABSTRACT (Maximum 200 words) Several standard benchmarks were implemented in order to study the real-time performance of the Alslys.037 Ada Compiler for the Inmos T800 Transputer. A limited comparison to the Transputer's native language, Occam, was possible. The key aspects that were investigated were the computational speed, using the Whetstone benchmark, the clock resolution, delay resolution, procedure call overhead and general performance. These were measured using the Performance Issues Working Group (PWIG) test suite. The Whetstone benchmark was implemented on the T800 in both Ada and Occam, making this measurement the most informative.				
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PREFACE

The work described in this report was authorized under Contract No. DAAL03-91-C-0034, Delivery Order No. 251. This work was started in June 1992 and completed in August 1992.

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EVALUATION OF ALSYS_037 Ada COMPILER

INTRODUCTION

The Edgewood Research, Development and Engineering Center is developing a Chemical Biological Mass Spectrometer (CBMS) containing an embedded system which utilizes the INMOS T800 Transputer. Although there are several programming languages available for systems development on the Transputer, one of the most widely used is Occam. Occam's popularity can be attributed to the fact that it is a high level language designed to express parallel algorithms and their implementation on a network of processing components. In addition, the Transputer may be considered an Occam machine; Occam provides the efficiency equivalent to that of programming a conventional computer at the assembly language level [INMOS 88]. However, given the Congressional Ada Mandate (Public Law 101-511 - Sec. 8092, and Public Law 102-172, Sec. 8073), Ada has been designated the systems development language of choice for Department of Defense software projects. The objective of this project was to evaluate the Alslys_037 Ada compiler for the Transputer; currently the only commercially available Ada compiler for the Transputer.

The general approach that was taken for this project was to run a series of software benchmark tests conforming to the following:

80x86 - DOS 5.0			TRANSPUTER	
BENCHMARK	Alslys Ada	Meridian Ada	Alslys Ada	Occam
Whetstone	X	X	X	X
PIWG	X	X	X	
Hartstone	X	X	X	

figure 1 - Test Plan

The Whetstone benchmark program [Curnow 76] was developed to compare processing power for scientific applications. The program goes beyond measuring pure floating point performance ('flops') by including features found in 'typical' scientific applications such as: conditional jumps, array indexing, integer arithmetic, procedure calls, and evaluation of elementary functions. The PIWG test suite [Pollack 90, Roy 90] contains a series of experiments that assist in the evaluation of processor performance, clock resolution and compilation efficiency. Hartstone [Weiderman 89] is a benchmarking tool for evaluating hard real-time performance.

The initial plan was to test these software benchmark systems across the Intel 80x86 and INMOS T800 platforms using the Alslys Ada compiler for 32-bit DOS, the Alslys Ada compiler

for the Transputer, and the Meridian Ada compiler for 32-bit DOS. The quantitative results from these tests would then be used as the basis for conclusions and recommendations.

TECHNICAL DISCUSSION

HARDWARE/SOFTWARE

The hardware system which was used to develop and test the benchmarks consisted of:

Host system - Gateway 2000: 80486DX/33MHz, EISA, 8MB RAM

Transputer - CSA Transputer board for PC: T800/20MHz, 4MB RAM

Once the DOS executables were generated, timings were measured on the 386/20MHz, 386/33MHz, and 486/33MHz systems. The 386 systems were equipped with 80387 math coprocessors.

The systems software used to support the project consisted of:

DOS 5.0

Alsys Ada - version 5.1 - 32 bit DOS compiler

Alsys Ada_037 - version 5.4.2 - Transputer compiler

Meridian Ada - version 4.1.1 - 32 bit DOS compiler

INMOS Occam Toolset - version D7205

Early in the project, the Meridian compiler was abandoned due to the volume of compile-time and run-time errors encountered with code which was successfully tested in the Alsyes environment. Time did not permit debugging and rewriting a large volume of code. Therefore, the revised test plan matrix conforms to the following:

BENCHMARK	Alsys Ada - 32 bit DOS			Transputer	
	80386/20MHz	80386/33MHz	80486/33MHz	Alsys Ada	Occam
Whetstone	X	X	X	X	X
PIWG	X	X	X	X	
Hartstone	X	X	X	X	

figure 2 - Test Plan - revised

ACTIVITIES

WHETSTONE: The Whetstone benchmark has been considered somewhat a standard benchmark for a number of years. Unlike the Drystone benchmark, Whetstone is intended to simulate 'typical' scientific applications through its utilization of a variety of routines. It does, however, fall short in several categories of contemporary scientific calculations. In particular, it uses small arrays, no multi-dimensional arrays are employed, it is dependent on the speed of floating point operations, and the number of elementary function evaluations is probably atypical of current programming models [INMOS 91, p259]. Despite these observations, it still provides a legitimate baseline for the evaluation required in this project. Whetstone was successfully coded and tested in both Ada and Occam, and run on the 80x86 and T800 platforms.

PIWG: The Performance Issues Working Group (PIWG) of the Association for Computing Machinery (ACM) has made available a series of Ada benchmarks which can be used in the evaluation of Ada compilers across a range of hardware platforms. The test suite assists in the evaluation of execution time and compilation time. It was determined for this project that the compilation time tests were of little value at this stage in the project; therefore, emphasis was placed on the evaluation of execution timings. In particular, there are four test areas that made up the critical area of performance testing. They are:

- | | |
|--|--|
| 1. Clock Resolution (A000090) | This test illustrates CPU clock resolution available to Ada. |
| 2. DELAY Resolution (Y000001) | Measures the resolution of the DELAY feature of Ada. |
| 3. Procedure Call Overhead (P000005/6/7) | Measures procedure call overhead time in Ada. |
| 4. Hennesy Tests (A000094A-K) | Series of tests which measure performance in a variety of areas including: recursion, integer and real matrix multiplication, and sorting (data movement). |

These tests were successfully performed in Ada on both the 80x86 and T800 platforms.

HARTSTONE: The Hartstone benchmark is a set of timing requirements for testing a system's ability to handle hard real-time applications [Weiderman 89]. The complete Hartstone benchmark consists of five categories of tests: PH Series, PN Series, AH Series, SH Series, and SA Series [Weiderman 89, p5]. The only test successfully implemented in Ada to date is the PH Series. This test provides feedback for a set of tasks which are periodic and harmonic.

The PH Series was successfully tested on the T800 platform in Ada; however, the 80x86 DOS tests failed to provide reliable results. Best estimation is that as the period in milliseconds began to approach the clock resolution available through the Ada/DOS environment, the system would "hang"; apparently attributable to DOS. Therefore, the quality of comparable 80x86/T800

results was compromised. Because of deadline constraints, it was determined that the Hartstone benchmarks could not be successfully implemented and therefore omitted from this report.

PROCEDURES

All benchmark development, testing and implementation was performed on the hardware and software mentioned on page two. Once the executables were generated, testing was conducted according to *figure 2* (page two). All compilations and binding/linking optimization options are contained in **APPENDIX A**.

RESULTS

During this study, particular attention was paid to the clock resolution. The CBMS system requires 3 microsecond resolution. which is one reason the T800 was selected, since it is capable of 1 microsecond resolution.

Test results are contained in the charts on the following three pages. A key point worth noting is that the Ada/Transputer environment is, in effect, a run-time environment. That is, the execution of the Ada generated code is supervised by the ISERVER. This run-time environment does not permit the Ada code access to the high priority one microsecond clock resolution available on the T800. The Occam environment, however, does permit Occam code one microsecond access. Therefore, perhaps one of the most interesting charts is the WHETSTONE comparison. The other charts, however, do provide valuable information on the comparison of Ada executable on 20MHz and 33MHz processors utilizing different architectures.

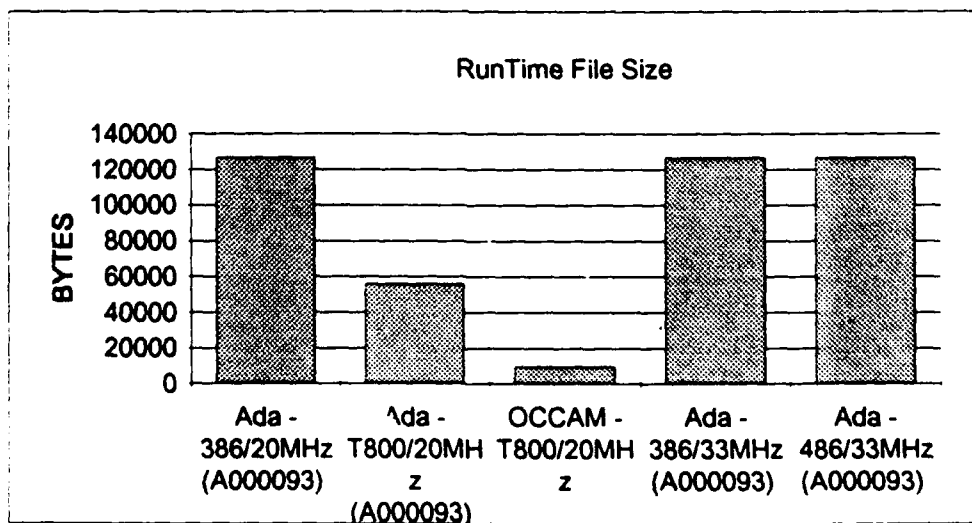
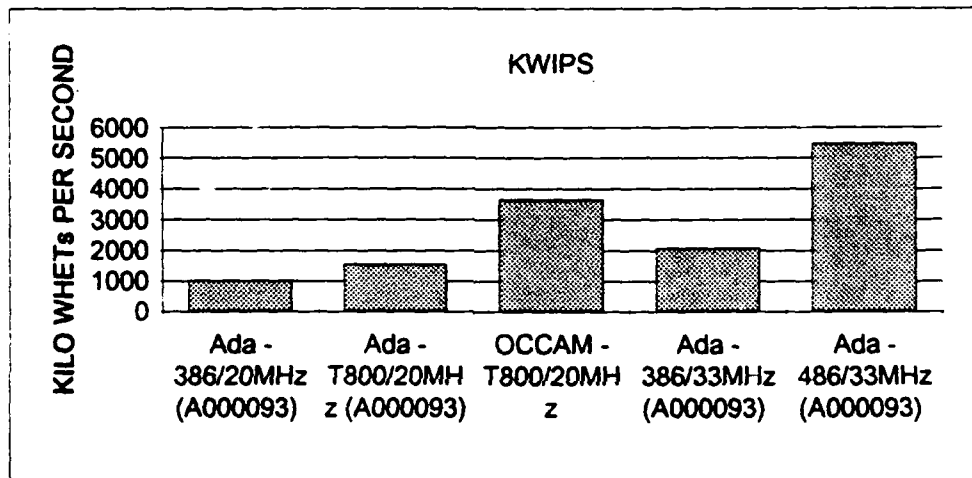
CONCLUSIONS

Real-time systems that involve events which occur with near megahertz frequencies require one microprocessor feature that is not supported by the 80x86 line of processors: microsecond resolution. This study concludes that the current Ada environments available fall short of providing this feature on the T800, even though it can be supported via Occam.

A variety of options exist in the pursuit of a solution to this problem. Perhaps the most interesting would be that of developing a software support system using both Ada and Occam. This option may satisfy both the timing constraints of fast real-time systems as well as the Congressional Ada Mandate. One item missing in permitting this recommendation is evidence of the realtime timing requirements of Occam. Comparative data, such as that provided in this report, illustrating Occam's statistics in similar PIWG and HARTSTONE implementations would be helpful. Such data could provide valuable insight as to whether or not Occam may be a viable alternative or supplement to the Ada development environment.

WHETSTONES

TARGET	KWIPS	RunTime File Size	File Type
Ada - 386/20MHz (A000093)	1010	126944	.EXE
Ada - T800/20MHz (A000093)	1541	55890	.BTL
OCCAM - T800/20MHz	3655	9646	.BTL
Ada - 386/33MHz (A000093)	2075	126944	.EXE
Ada - 486/33MHz (A000093)	5489	126944	.EXE



CLOCK RESOLUTION (A000090)

Alsys Ada

System	Time (seconds)
Transputer (T800-20/20MHz)	0.000061035156250
30386/20MHz (DOS)	0.000854492187500
80386/33MHz (DOS)	0.000854492187500
80486/33MHz (DOS)	0.000854492187500

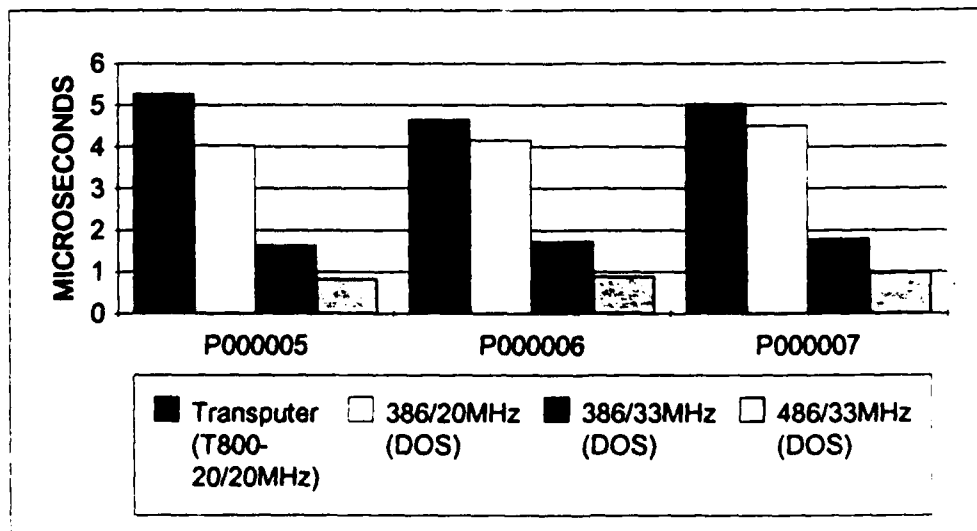
DELAY RESOLUTION (Y000001)

Commanded	Transputer (T800-20/20MHz)	386/20MHz (DOS)	386/33MHz (DOS)	486/33MHz (DOS)
0.00097	0.00115	0.00171	0.00171	0.00171
0.00195	0.00213	0.00256	0.00256	0.00256
0.00390	0.00415	0.00427	0.00427	0.00427
0.00781	0.00805	0.00854	0.00854	0.00854
0.01562	0.01599	0.01630	0.01630	0.01630
0.03125	0.03161	0.03174	0.03174	0.03174
0.06250	0.06280	0.06262	0.06262	0.06262
0.12500	0.12530	0.12525	0.12524	0.12524
0.25000	0.25024	0.25055	0.25055	0.25055
0.50000	0.50036	0.50031	0.50031	0.50031
1.00000	1.00030			1.00067
2.00000	2.00024			2.00049

PROCEDURE CALL OVERHEAD

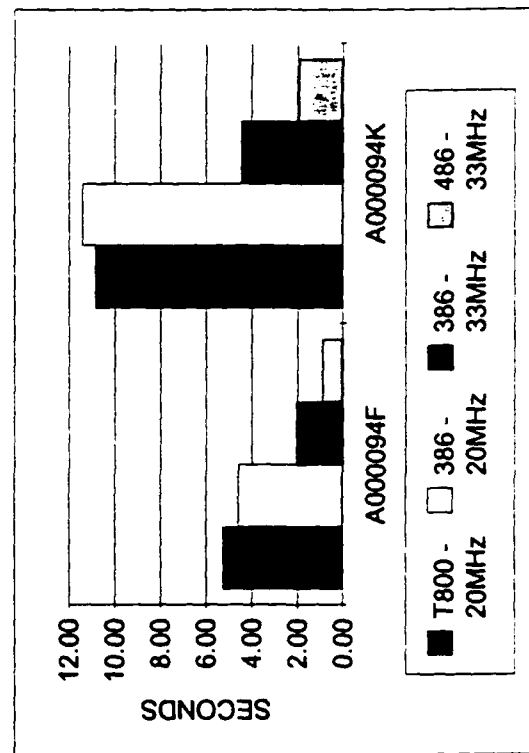
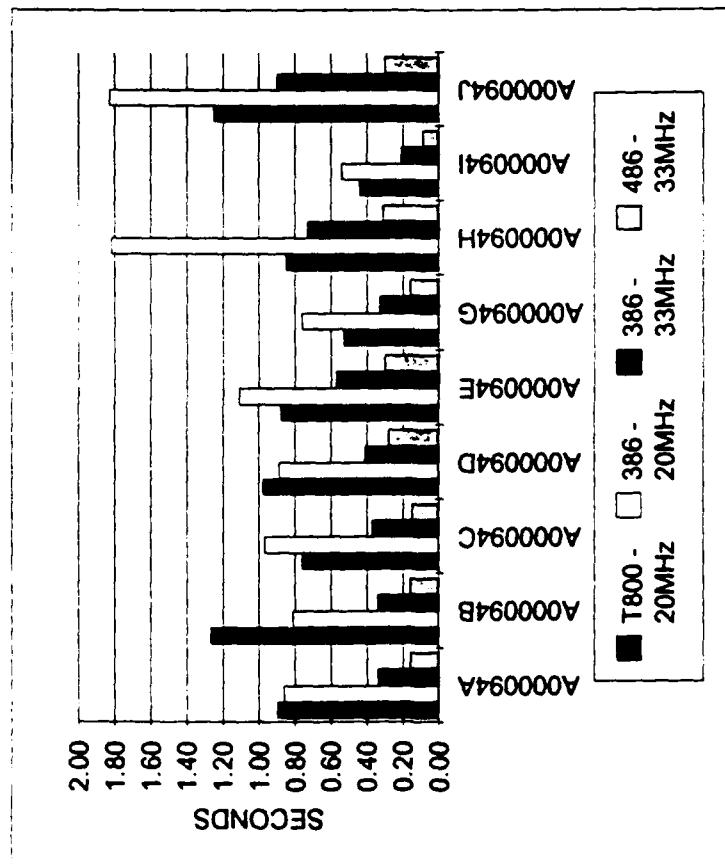
Alsys Ada - time in microseconds

Test	Transputer (T800-20/20MHz)	386/20MHz (DOS)	386/33MHz (DOS)	486/33MHz (DOS)
P000005	5.27	4.04	1.63	0.84
P000006	4.66	4.16	1.72	0.89
P000007	5.03	4.51	1.79	0.98



Hennessy Tests - Ada Results

Test Description	TEST ID	T800 - 20MHz	386 - 20MHz	386 - 33MHz	486 - 33MHz
Permutations - 43,300 - highly recursive	A000094A	0.90	0.86	0.34	0.16
Towers of Hand - highly recursive	A000094B	1.27	0.81	0.34	0.16
Eight Queens - solved 50 times	A000094C	0.76	0.97	0.37	0.15
Integer Matrix Multiply - 40X40	A000094D	0.98	0.89	0.41	0.28
Real Matrix Multiply - 40X40	A000094E	0.88	1.11	0.57	0.30
Quicksort - 5K random Integers	A000094G	0.53	0.76	0.33	0.16
Bubblesort - 5K random Integers	A000094H	0.85	1.82	0.73	0.31
Tree Insertion Sort - 5K random Integers	A000094I	0.44	0.54	0.21	0.09
FFT (256 point complex) - performed 20 times	A000094J	1.25	1.83	0.90	0.30
Puzzle Problem - CPU intensive	A000094F	5.27	4.57	2.04	0.91
Ackermann's Function - performed 10 times	A000094K	10.85	11.41	4.44	1.93



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APPENDIX A

OPTIMIZATION

All code was compiled and linked taking advantage of optimization features provided by each specific development environment.

Ada - DOS

Compiler - Alsys Ada for 32-bit DOS - version 5.1

Compile options - IMPROVE=(CALLS = INLINED
 REDUCTION = EXTENSIVE
 EXPRESSIONS = EXTENSIVE)

CALLS = INLINED: Call will be inlined for subprograms that aren't directly
 or indirectly recursive in response to INLINE pragma.

REDUCTION = EXTENSIVE: Performs analysis of intermediate program
 representation to eliminate numerous run-time
 checks and removal of dead code.

EXPRESSIONS = EXTENSIVE: Performs common subexpression elimination
 and additional register optimization.

Bind options - TIMER = FAST

TIMER = FAST: High resolution timer used for the
 implementation of the DELAY statement.

Ada - Transputer

Compiler - Alsys Ada for the Transputer - version 5.4.2

Compile options - IMPROVE=(INLINE = PRAGMA
 REDUCTION = EXTENSIVE
 EXPRESSIONS = EXTENSIVE)

INLINE = PRAGMA: Same as CALLS = INLINED above.

REDUCTION = EXTENSIVE: Same as REDUCTION = EXTENSIVE above.

EXPRESSIONS = EXTENSIVE: Same as EXPRESSIONS = EXTENSIVE
 above.

Bind options - FAST_MAIN = YES, FAST_TASK = YES

FAST_MAIN = YES: Attempt to allocate the primary stack of the main program in a low-addressed area which could be mapped to the internal on-chip memory of the Transputer.

FAST_TASK = YES: Attempt to allocate the primary stack of the task in a low-addressed area which could be mapped to the internal on-chip memory of the Transputer.

Occam

Compiler - INMOS Occam Toolset - version D7205

Compiler options - /a /t8 /h

 /a: Prevents compiler from performing alias checking, and prevents usage checking.

 /t8: Compile for T800 processor.

 /h: Produces code in HALT mode.

Linker options - /t8 /h

 /t8: Specifies T800 as target processor.

 /h: Generates a linked unit in HALT mode.

Code Collector options: /t

 /t: Creates a bootable file for a single transputer.

Host file server: /se

 /se: Terminates the server if the Transputer error flag is set.